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Effect of Natural Jordanian Volcanic Tuff on Growth, Irrigation Water Saving and Leaves Mineral Content of *Salvia officinalis*

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ABSTRACT

Environmental stresses such as low soil moisture and soil nutrient deficiency are the main causes for low productivity in arid and semi-arid regions. Soil amendments are one solution to minimize soil moisture evaporation and to improve plant nutrients uptake. The current study was carried out to examine the effect of different weathered and fresh volcanic tuff (WVT and FVT, respectively) application rates available in Jordanian market on growth, irrigation water saving and leaves mineral content of salvia *Salvia officinalis*. Plant growth was significantly ($P \leq 0.01$) decreased by increasing WVT/FVT application, where the maximum reductions were detected in pure WVT and FVT treatments. Leaves sodium concentration were significantly ($P \leq 0.05$) increased by 2 to 3 folds by VT application, however, other essential elements such as nitrogen, iron and manganese were decreased. The water consumption in VT amended soils was reduced from 46.5 to 67.8% and to the same extent as the total plant biomass (reductions ranged from 39 to 72%). Consequently, very marginal differences were observed between salvia plants grown in VT and pure soil treatments in water use efficiency. The high water potential of VT (i.e. can cause excess soil moisture around root system) might actually interfere with water uptake by oxygen-deprived roots and reduce plant growth. The plant growth reduction in VT amended soils might be also partially due to the slight increases in salt content and pH of growing substrates. Further research is needed to determine the effect of other types of Jordanian VT, particularly those with high zeolite and low salt and calcium carbonate content.

Keywords: Irrigation Water Saving, Leaves Mineral Content, Salt Strees, Volcanic Tuff, Water Stress.

INTRODUCTION

Low moisture content and soil nutrient defciency are primary causes for low crop productivity under arid and semi-arid conditions in Jordan. Agriculture is the major consumer of water in Jordan, where about 72% of Jordanian annual water demand goes for agricultural uses (Ministry of Water and Irrigation, 2008). Under high temperature environment such as Jordan, irrigation is a very wasteful practice, where huge quantities of water are evaporated during irrigation (Hudson, 1994; Montemurro, 2004; Gholizadeh et al., 2006). Jordanian soils are suffering from nutrient deficiency, which is mainly due to high soil calcium carbonate content (15-35%), alkaline condition and low soil organic matter (Al-Rawashdeh and Abdel-Ghani, 2008). Therefore, under these low input conditions (drought and low soil fertility), water-saving agriculture practices and improving nutrient use efficiency are essential to

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enhance the economic yield and give the opportunity for small scaled farmers to reduce their input cost per unit area.

One possible solution to minimize the effect of drought and to conserve and enhance soil fertility is using soil amendments (Reganold, 1995; Baikova and Semekhina, 1996; Liu et al., 1996; Conacher and Conacher, 1998; Loboda, 1999). A soil amendment is any organic or inorganic material could be added to a soil to improve its physical properties with a goal to provide a better environment for roots growth and development (Hudson, 1994; Montemurro, 2004; Gholizadeh et al., 2006). Natural zeolite is among the minerals often used in attempts to develop new substrates for plant growing: for seedling production, rooting of cuttings, potting of ornamental plants etc. Natural zeolite' strong sorption properties, high cation exchange capacity (CEC) and high macro- and micro-nutrients content make them an attractive alternative to peatmoss and other natural products used in agricultural applications (e.g., Ming and Dixon, 1986; Ibrahim et al., 2001; Mohammad et al., 2004; Gul et al., 2005; Noor et al., 2006). Jordan has rich mineable deposits of zeolites with attractive physical and chemical properties for agriculture; it has been estimated that zeolite reserves in various areas in Jordan is about 2037.2 million ton (Natural Resources Authority NRA; 2010). In several literatures, zeolite was reported to be useful in various agricultural crops as a soil conditioner in order to improve drainage and aeration, reduce leaching of pesticides and fertilizers from the soil and save water during irrigation (eg., Ming et al., 1995; Baikova and Semekhina, 1996; Loboda, 1999). While many studies investigated the ability of natural zeolites and other amendments such as lime and red mud to reduce heavy metal availability in contaminated soils (Garau et al. 2007; Bertocchi et al. 2006; Gray et al. 2006), the influence of fresh and weathered volcanic tuff (VT) on growth, irrigation water saving and nutrient uptake by plants remains poorly investigated. Therefore, the present study was carried out to: (i) assess the effects of Jordanian VT as a soil amendment on plant growth and yield of salvia (*Salvia officinalis*), (ii) estimate the amount of irrigation water that could be saved from using Jordanian VT and (iii) investigate the influence Jordanian VT on leaves mineral content.

Materials and Methods

The soil used in this experiment was collected from the National Center for Agricultural Research and Extension (NCARE), Rabba, southern part of Jordan (31° 16' N, 35° 45' E and ca 920 meters above sea level). The soil was air-dried and sieved through a 2 mm mesh. The soil is characterized by having a sandy loam texture soil (56 % sand, 15 % silt, 29 % clay), alkaline pH (about 8.1), 1.3 % organic matter, 640 ppm total nitrogen (N), 18 ppm available Olsen phosphorus (P), 22 % calcium carbonate, CEC of 52.7 milli-equivalent (mEq) 100 g^{-1}, and electrical conductivity (1 : 1) of 0.4 dS m^{-1}.

Two samples of VT were obtained from the Green Technology Group Al Aritayn /Al-Marfaq/ Jordan. The first sample was fresh volcanic tuff (FVT) which is distinguished by black to light gray color. It consists of volcanic pyroclastics, which is composed of fresh sideromelane and sometimes cemented by carbonates. The second sample was weathered volcanic tuff (WFT) which consists of palagonitized tuff with dark brown to reddish brown color. The pyroclastics are mainly cemented by calcite and some zeolite minerals.

The experiment was carried out under partially controlled greenhouse conditions at the NCARE, Rabba, south part of Jordan during the period extended from 15th March to 15th October, 2010. The air temperature ranged from 23 to 28_C during the day and 16–22 _C during the night. Salvia or common sage (*Salvia officinalis*) was use in this invistigation. Salvia is a perennial, evergreen subshrub, with woody stems, with gray-green foliage, and blue to purplish flowers. It is a member of Lamiaceae family and is native to Mediterranean region (Angelova et al. 2004), though it has naturalized in many places throughout the world. It has a long history of medicinal and culinary use, and in modern times as an ornamental garden plant. The common name "sage" is also used for a for a number of related and unrelated species. Salvia (local variety, Baladi) seedlings were grown in plastic pots. Nine different growing media were used: pure soil, pure weathered volcanic tuff (WVT), pure fresh volcanic tuff (FWT), 3 : 1, 1 : 1, and 1 : 3 (v/v) soil to WVT, and 3 : 1, 1 : 1 and 1 : 3 (v/v) soil to FVT. The experimental design was Randomized Complete Block Design (RCBD) with three replicates and each replicate was represented by 3 plants grown in three separated pots. Sealed plastic pots, 26 cm in diameter and 40 cm deep were filled with 8 liter air-dried soil or equivalent volume of WVT, FVT and media mixture (WVT and FVT with soil). Pots were irrigated once every other day and kept free of weeds by hand weeding. All treatments were maintained at 80% of available water of the pure soil treatment (i.e. by adding 80% of available water that used in the control or pure soil treatment)**.** Soil was saturated with water and the weight of the soil after drainage stopped at (-0.33 bar) was recorded to determine field capacity (FC) and the permanent wilting point (PWP) was determined by exposing soil samples to -15 bar for 3 days. Soil moisture contents of the two samples (at FC and PWP) were measured by weighing soil samples before and after oven drying at 105 °C for 24 h and the weights divided by the weight of the oven-dry soil. The available water in the samples was determined as the difference between the soil water content at FC and that at PWP. The moisture statues of each pot were determined gravimetrically with analytical balance (0.1 g accuracy) by weighing the pots including plants. The loss of moisture by transpiration and evaporation were compensated and recorded at irrigation time, and the total amount of water added was used later to estimate water use efficiency (WUE). Complete compound fertilizer [growth 20 : 20 : 20 + trace elements corresponding to N : P_2O_5 : K_2O + (Mg, Fe, Zn, Cu, Mn and B), respectively] as powder was split applied at a rate of 60 kg ha^{-1} (0.32 g pot^{-1}).

Parameters recorded

At the end of the experiment, plants were cut down to soil surface and consequently separated into leaves and shoots and thereafter, number of the leaves and the leaves area per plant were determined. In addition, roots were isolated after careful cleaning from soil residues. The leaves, the shoots and the roots were subsequently dried in a drying chamber to a constant weight at 75 ºC for 72 hours to determine the dry weight of these organs. Other parameters such as plant height (cm) and shoot length (cm) as well as main stem diameter (mm) were measured two days before harvesting.

Dried leaves were grounded to reduce the material to a fineness suitable size for chemical analysis using a mechanical grinder and subsequently stored in air tight plastic containers for chemical analyses. Total nitrogen (N) content was determined by digesting 1 g dry leaf samples using Macro-Kjeldahl procedure. Phosphorus (P) content was determined using a spectrophotometer. Ground samples were digested with nitric acid for potassium (K) and sodium (Na) as well as micronutrient (Iron, Fe; Manganese, Mn and Magnesium, Mg) analyses using atomic absorption spectrophotometer (Model Analyst 300, Perkin Elmer). All procedures were used as described in Tandon (1995). Mineral identification of WVT, FVT and soil was performed using Shimadzu X-ray diffractometer (XRD – 6000) at 40 kV and 30 mA (Awwad et al., 2009). In addition, mineral composition, CEC and particle sizes were determined (Ghrair et al., 2009). Apparently, homogeneous individual samples of WVT, FVT and soil were analyzed by X-ray fluorescence spectrometer (XRF) (Shimadzu XRF-1800) at 40 kV and 95 mA for major oxides (Awwad et al., 2009).

The amount of water added was recorded from the beginning to the end of the experiment to estimate the amount of irrigation water saved using the following formula:

$$IWS\% = \frac{WPST - WT}{WPST} \times 100\%$$

where

IWS is irrigated water saved

WPST is the amount of water applied to pure soil treatment (the control)

WT is water applied to WVT/FVT treatments

Water use efficiency (WUE) can be defined as the units of a crop produced from each unit of water added to the growing medium (e.g., g dry weigh kg^{-1} water). The more crop yield that's produced per unit of water the greater is the WUE. WUE was estimated for different water treatments by calculating the ratio between the dry total plant biomass produced in g and kg water added during the experiment to each treatment.

Statistical analysis

Analysis of variance (ANOVA) was used to test the treatments effect using randomized complete block design (RCBD) by applying the following mathematical model (Steel and Torre, 1980): $y_{ij} = \mu + \tau_i + \beta_j + \varepsilon ij$, where τ_i represents the effect of treatment i, such that the average of each treatment , $\overline{T} = \mu + \tau_i$ such that the average of each block is $\overline{B} = \mu + \beta_j$, εij are the residuals, the deviations of each observation from their expected values. Fisher's LSD was used as a method for comparing VT treatment group means with pure soil treatment (the control) after the ANOVA F-test null hypothesis of equal means has been rejected at $P \leq 0.05$.

Results

According to X-ray diffraction analyses, WVT and FVT have different mineral assemblages than the soil. The XRD chart (Fig. 1 A) shows that WVT contains series of secondary minerals such as calcite, phillipsite, hematite, magnetite, gypsum, and smectite. On the other hand, the mineral content of pure soil sample was quartz, calcite, smectite and kaolin (Figure 1 B). Figure 1 C indicates that primary minerals in FVT are existed, mainly anorthite, olivine and amorphous glass. The analyses of major oxides are given in weight percentage (Table 1). In comparison with FVT, silica and aluminum oxides value was low, while calcium (Ca), magnesium (Mn) and K oxides content were high in the WVT. Na_2O concentration in pure WVT and FVT treatments was up to 24 times higher than controlled soil. $CaCO_3$ concentration in WVT was 1.1 and 1.4 times higher than pure soil and FVT, respectively. At the end of the pot experiment, the values of pH, electrical conductivity (EC), and salinity for nine different growing media mixtures were estimated (Table 2). Amending soil with WVT and FVT did not show a very remarkable (although significant at $P \leq 0.01$) increase in media pH. The salinity significantly ($P \leq 0.01$) increased up to 2 to 5 times more in FVT and WFT, respectively.

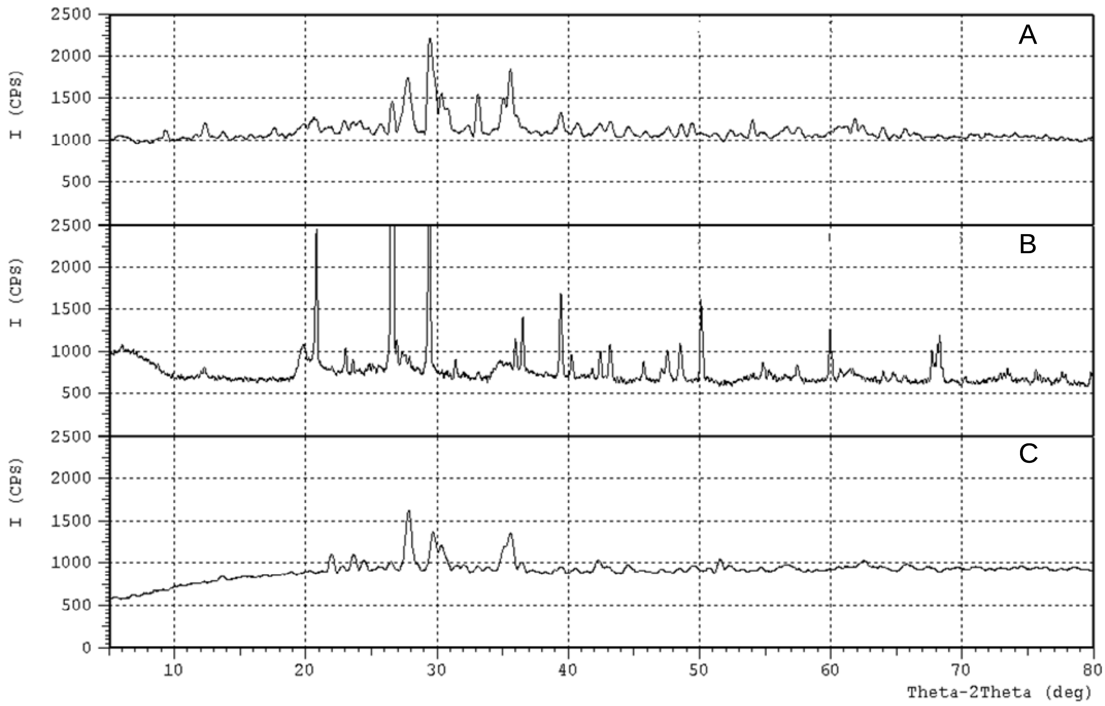

Figure 1. X-ray diffractometer patterns of (A) highly weathered volcanic tuff (WVT), (B) soil sample, and (C) fresh volcanic tuff (FVT).

Table 1. Chemical composition of fresh volcanic tuff (FVT), weathered volcanic tuff (WVT) and soil used in the experiment.

Oxides (%)	FVT	WVT	Soil
SiO_2	43.41	41.54	51.45
Al_2O_3	14.25	12.28	10.35
Fe_2O_3	11.59	11.35	4.93
TiO_2	2.09	2.24	0.90
P_2O_5	0.47	0.41	0.58
CaO	9.58	13.00	12.30
MgO	5.91	8.89	1.37
Na_2O	1.73	1.19	0.07
K_2O	0.64	1.01	0.86
$CaCO_3$	17.10	23.70	21.50

Effect of VT amendment on growth parameters

All tuff treatments caused significant ($P \leq 0.01$) reductions in vegetative growth and root dry weight (g) as well as other growth related traits such as plant height, leaves area per plant, main stem diameter and average number of branches per plant (Figure 2-9). In general, the low WVT/FVT application rates reduced the growth parameters to a lesser extent than high

WVT/FVT treatments (Figures 2 to 6). The reduction in growth parameters was more prominent with pure WVT and FVT treatments. Results indicates that the rate of VT is negatively proportional with root dry weight (r= -0.97* and -0.95* for WVT and FVT, respectively), however, non-significant associations was detect with vegetative growth dry weight, although negative (r = -0.72 and -0.75, respectively). The reductions in vegetative growth and root dry weight in WVT treatments ranged from 39 to 72% and from 41.2 to 69.1%, respectively (Fig. 2), the lowest reductions were observed at 3:1 soil/WVT treatment and highest reductions in pure WVT treatment. Plant vegetative growth was reduced by 62.3%, 50% and 81%; root dry weight reduced by 48.6%, 58.8% and 80.7% in 3:1, 1:1 and 1:3 soil/FVT treatments compared with the soil pure treatment, respectively. Plant height was significantly decreased ($P \leq 0.01$) compared to the pure soil treatment (the reductions ranged from 15.5 to 47.2%). All growth related traits significantly ($P \leq 0.01$) contributed to the reduction in plant vegetative growth production (Figure 2-9). The maximum reductions in the growth-related traits were observed in pure WVT/FVT treatments, while the minimum reductions were detected at low WVT/FVT application rates (Figures 3 to 9).

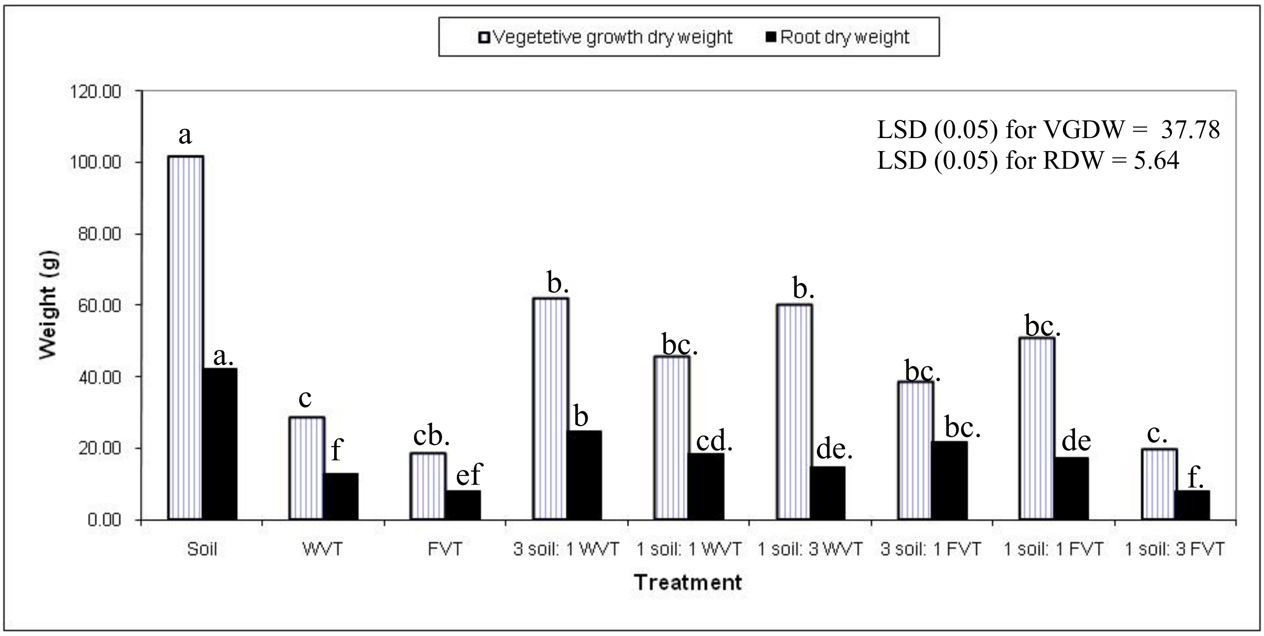

Figure 2. Effect of different growing media on vegetative growth dry weight (VGDW) and root dry weights (R. Treatments followed by the same letter are not significantly different at P < 0.05.

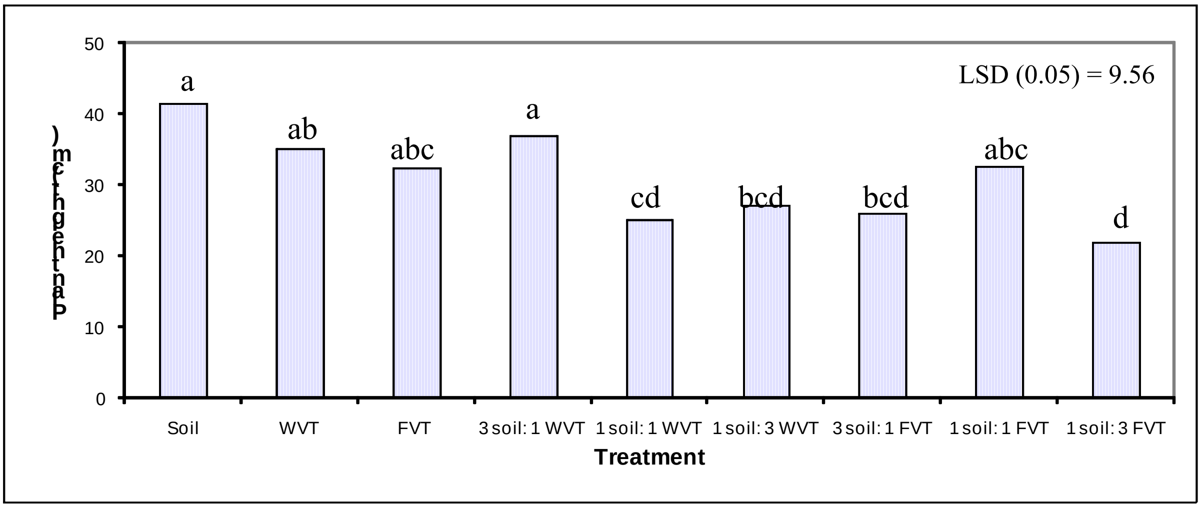

Figure 3. Effect of different growing media on plant height. Treatments followed by the same letter are not significantly different at P<0.05.

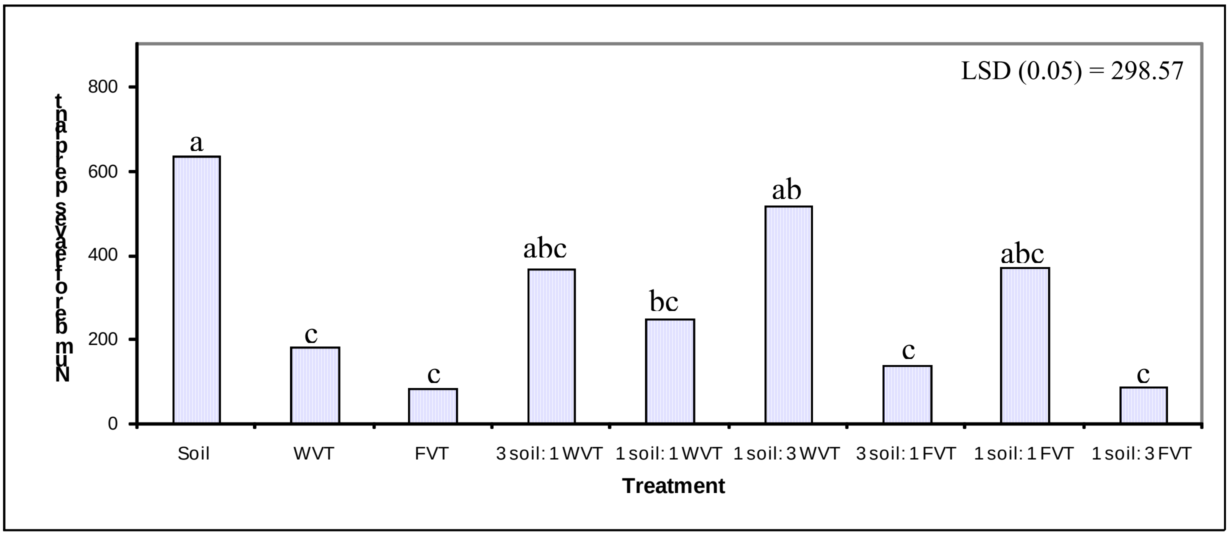

Figure 4. Effect of different growing media on number of leaves per plant. Treatments followed by the same letter are not significantly different at P<0.05.

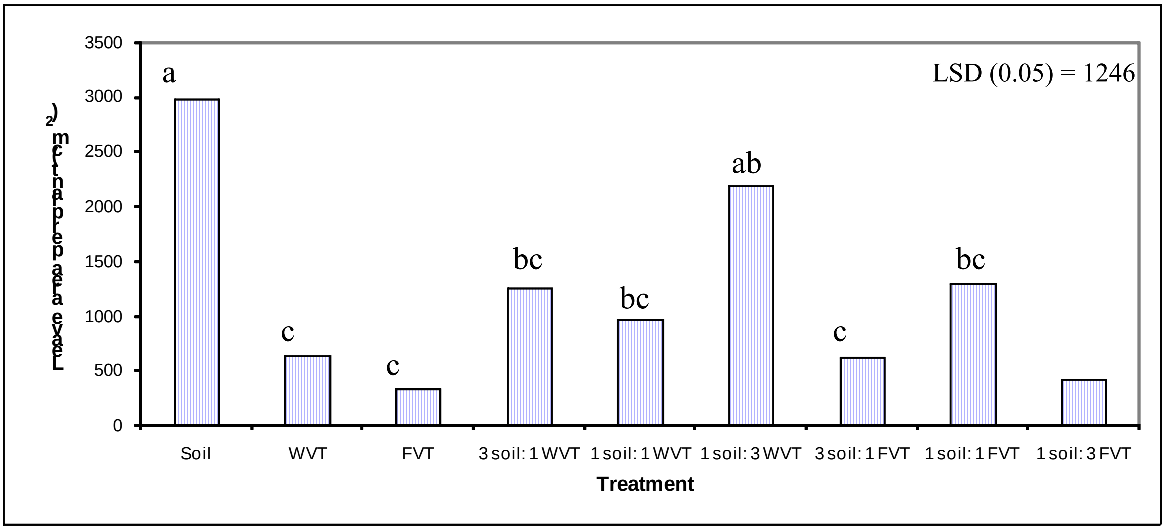

Figure 5. Effect of different growing media on total leave area per plant (cm2). Treatments followed by the same letter are not significantly different at P<0.05.

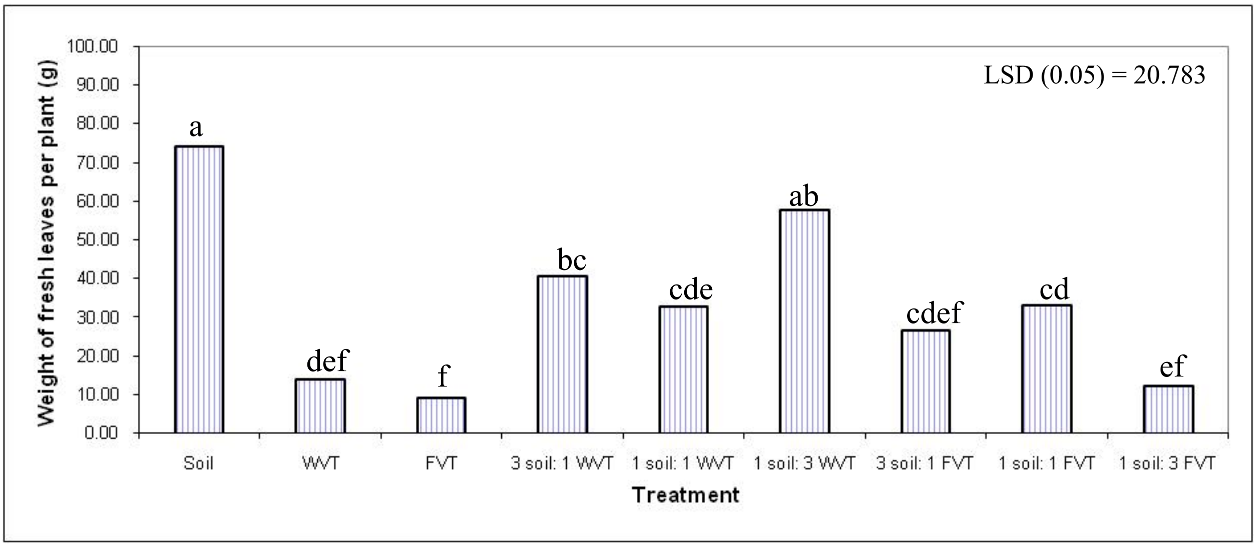

Figure 6. Effect of different growing media on total leaves fresh weight (g). Treatments followed by the same letter are not significantly different at P<0.05.

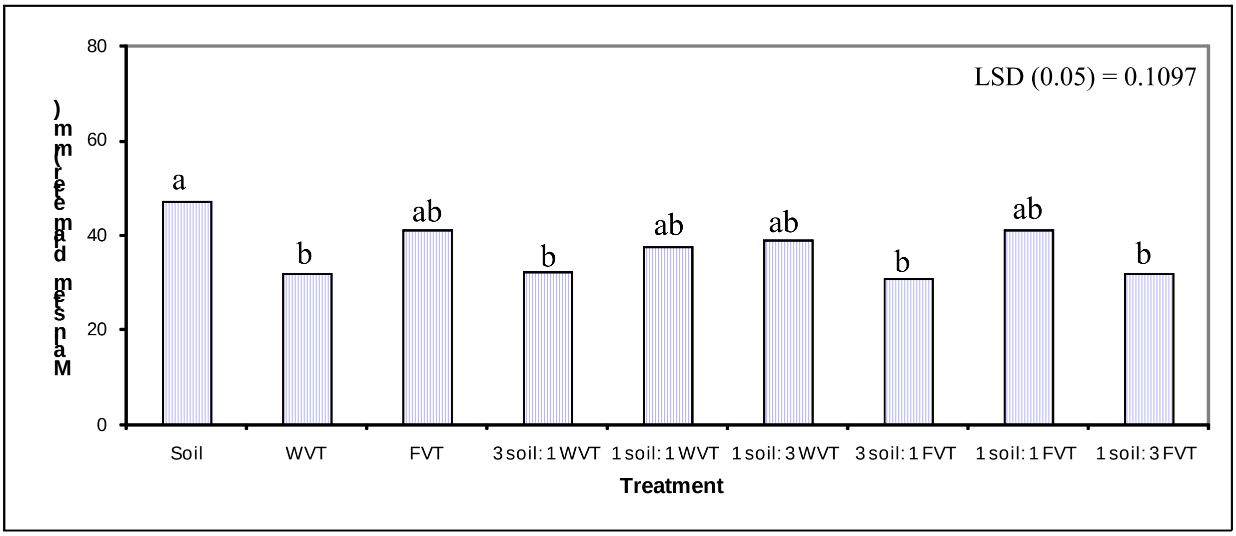

Figure 7. Effect of different growing media on plant main stem diameter (mm). Treatments followed by the same letter are not significantly different at P<0.05.

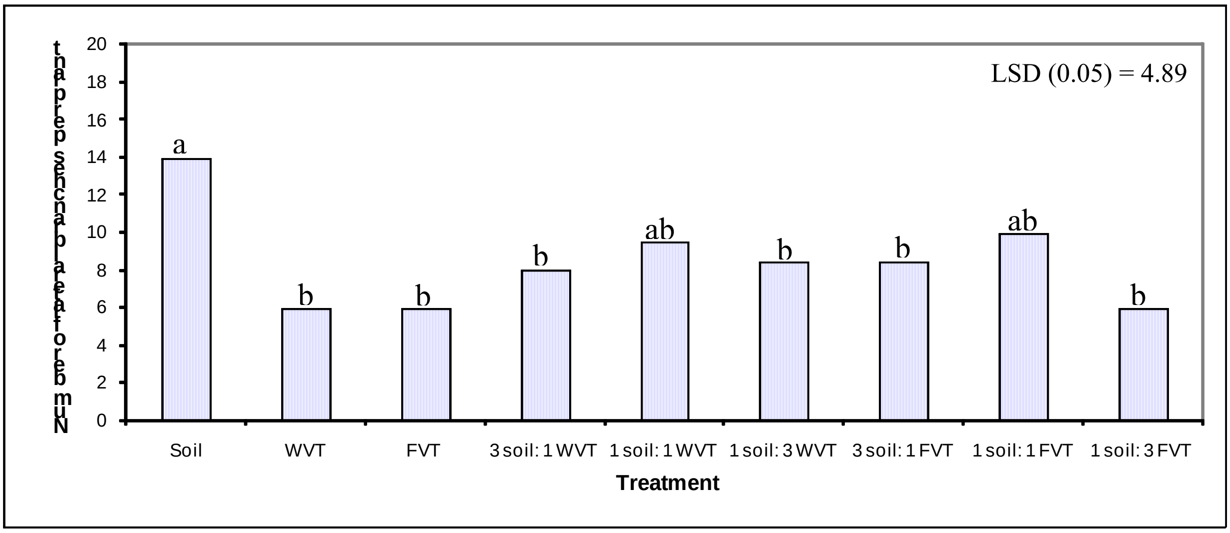

Figure 8. Effect of different growing media on number of lateral branches per plant. Treatments followed by the same letter are not significantly different at P<0.05.

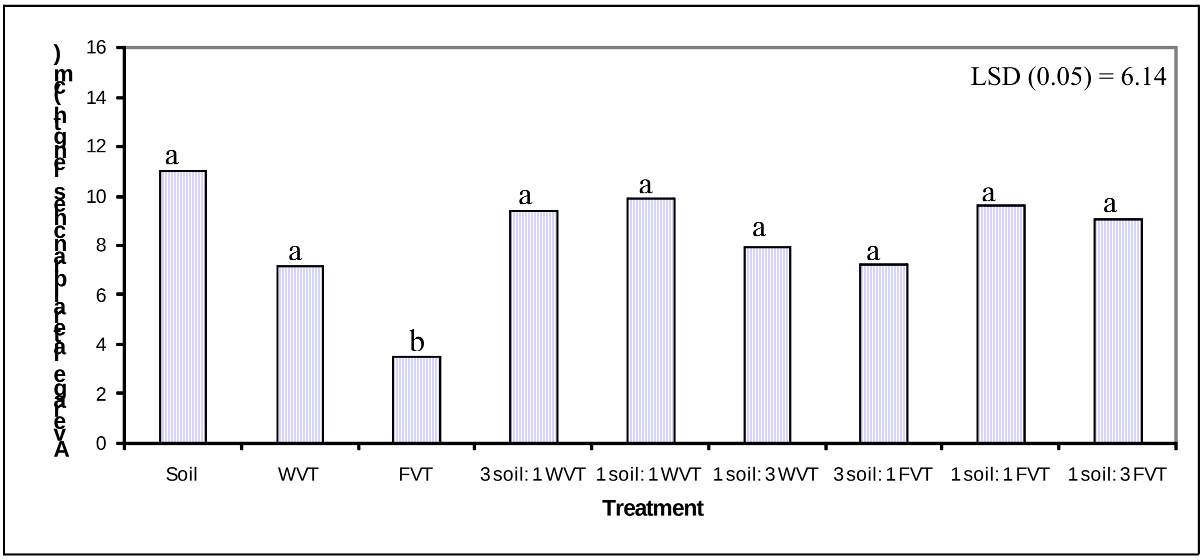

Figure 9. Effect of different growing media on average lateral branches length per plant. Treatments followed by the same letter are not significantly different at P<0.05.

Effect of VT application on agricultural water saving and water use effciency (WUE)

One objective of this study was to estimate the amount of irrigtaion water that could be saved using WVT/FVT as an agricultural soil amendment (i.e. to examine the possibility to reduce watering frequency and its effect in improving drought tolerance in some agricultural crops). The amount of water added (mm) in each treatment and the amount of water saved (%) in all treatments compared to pure soil treatment are presented in Figure 10. Results showed that WVT/FVT can act as water saver. The amount of irrigated water saved ranged from 46.5 to 63.0% and from 50.7 to 67.8% in soils amended with WVT and FVT, respectively. When pure WVT and FVT substrates were used, about 51.3 and 75.1% of irrigation water was saved respectively. Irrigation water was saved by 53.2% and 57.4% using low ZT/VT application rate (3:1 soil/VT treatments). Results showed considerable differences in water use effecincies ($P \leq 0.01$) among all soil treatments, ranging from 2.2 g kg^{-1} in pure VT and 1:3 soil/VT treatments to 5.5 g kg^{-1} in 3:1 soil/VT treatment (Figure 11). In general, somewhat higher WUE values were observed in treatments received higher VT rates than in the pure soil treatment. It could be explain as function of mineralogy of VT, pores and voids content.

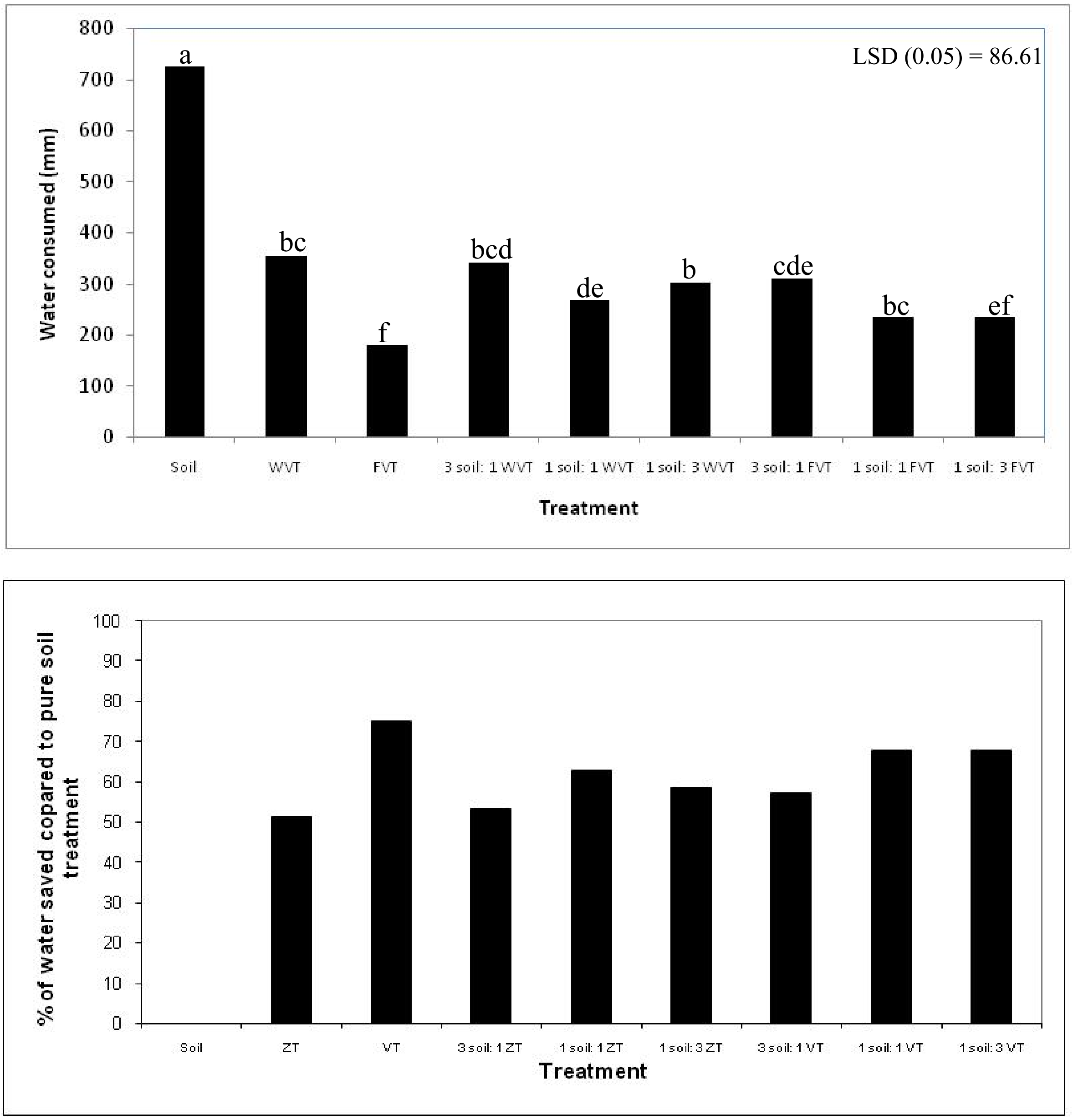

Figure 10. A. The amount of water consumed (mm); B. The amount of water saved in treatments compared to pure soil treatment.

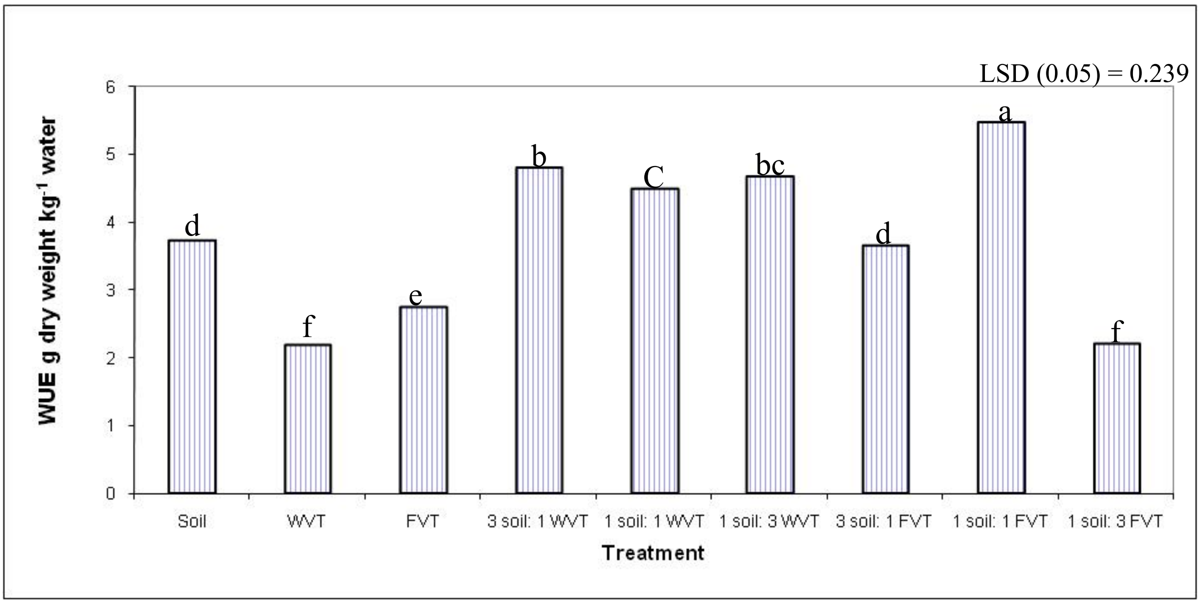

Fig 11. Water use efficiency for different growing media. Treatments followed by the same letter are not significantly different at P<0.05.

Effect of VT soil amendment on mineral content of leaves

Leaves N content were significantly ($P \leq 0.01$) decreased when the plants were grown in WVT and FVT amended soils and in WVT and FVT pure substrates, although nonsignificant. Nonsignificant effects of WVT/FVT application on leaves P and K content were noticed as compared to the pure soil treatment. Leaves grown in pure soil treatment had significantly ($P \leq 0.01$) the highest available Fe (1565.75 ppm) and Mn (109.86 ppm) compared to other WVT/FVT treatments (Table 2). Leaves Mg content in pure soil treatment were not significantly differed from those obtained in all VT treatments. Na content in plant leaves grown in pure VT treatments was two to three times higher than that detected in pure soil treatment.

Table 2. Effect of WVT and FVT on soil pH, EC and Salinity as well as leaves mineral composition of *Salvia officinalis* at different application rates.

Media type	pH	EC µS cm^{-1}	Salinity g l^{-1}	N (%)	P (%)	K (%)	Na (%)	Fe (ppm)	Mn (ppm)	Mg (%)
Soil	8.1d	316h	0.199h	3.24a[(1)]	0.10bcd	1.17a	0.37c	1870.1a	109.86a	0.42a
WVT	8.5b	1501a	0.946a	2.20a	0.09cde	0.79c	0.96b	1324.4bc	17.11e	0.39a
FVT	8.6a	871d	0.549d	1.65a	0.07e	1.45a	1.35a	1040.9bc	38.80de	0.33a
3 soil: 1 WVT	8.2cd	691f	0.435f	2.60a	0.11bc	1.34a	0.80b	1207.3bc	86.49b	0.34a
1 soil: 1 WVT	8.2c	1005c	0.633c	2.33a	0.12b	1.39a	0.87b	1152.7bc	73.27b	0.39a
1 soil: 3 WVT	8.2c	1144b	0.721b	2.05a	0.15a	1.42a	0.91b	1485.2a	67.60b	0.40a
3 soil: 1 FVT	8.1d	548g	0.345g	2.64a	0.13b	1.43a	0.81b	1334.5bc	73.62b	0.41a

Media type	pH	EC µS cm^{-1}	Salinity g l^{-1}	N (%)	P (%)	K (%)	Na (%)	Fe (ppm)	Mn (ppm)	Mg (%)
1 soil: 1 FVT	8.1d	691f	0.435f	1.88a	0.08de	1.16ab	1.11ab	1149.9bc	47.81cd	0.28a
1 soil: 3 FVT	8.1d	817e	0.515e	1.64a	0.10bcd	1.26a	1.17ab	833.5c	31.78de	0.33a
LSD (0.05)	0.090	9.46	0.031	ns	0.0268	0.389	0.370	506.67	23.102	ns

(1)Means in each column for each followed by the same letter are not significantly different

Discussion

Correlation of the XRD charts clearly shows that no secondary minerals have formed in FVT. In WVT, calcite is formed; peaks for phillipsite can be observed. The XRD study, therefore, shows that the amorphous glass in FVT was altered into secondary minerals in WVT. Ibrahim and Hall (1996) reported that the formation of zeolites, calcite, smectite, is associated with the transformation of sideromelane into palagonite by reaction with percolating water in an open hydrological system. Zeolites are formed in nature when water of high pH and high salt content interacts with volcanic ash, volcanic glass and primary aluminum-silicate minerals causing a rapid crystal formation (Oste et al., 2002). Zeolites are secondary minerals, which can be defined as crystalline hydrated alumino silicates of alkali and alkaline earth cations forming an infinite three-dimensional framework (Mumpton, 1977). The differences in chemical composition between FVT and WVT can be explained by the transformation and alteration of FVT into WVT.

Soil pH is one of the most common measurements in soil laboratories. According to Eberl (1995), the plant uptake of nutrients is strongly influenced by pH. The pure soil treatment and the WVT can be classified as moderately alkaline. Addition of WVT or FVT to the soil did not alter soil pH, which could be explained by the behavior of the soil as pH buffer. Similarly, other studies (Khoury et al. 2003; Hach Company 1993) classified VT as slightly strongly alkaline . Based on EC and pH values as well as according to Hach Company (1993) and Khoury et al. (2003) criteria, the eight growing pure VT treatment and media mixtures amended with VT can be classified as calcareous slightly saline. The reductions in salvia growth by addition of VT can be attributed to reduction of micronutrients availability. Furthermore, the water absorption reduction caused by the low water potential in the root environment as a consequence of salt stress (Flower et al. 1990; Munns et al., 1995). In Na^+ saturated tuff, the effects of ions on essential nutrients uptake such as K^+, Ca^{++}, NO_3^- are also of particular interest. The Na^+ content of saliva leaves grown in the WVT and FVT treatments was 12 and 17 times more than in pure soil treatment, respectively. Ions at high concentrations (e.g. Na^+) are taken up at high rates, which may lead to the suppression of uptake of other essential ions and their transportation to the shoot (Gorham and Wyn Jones, 1993; Mer et al., 2000). The growth reduction in saline soil could also be the result of toxic effects related to the accumulation of Na^+ ion (Ehert et al., 1990; Brugnoli and Lauter, 1991; Abdus Salam et al., 1999; Saneoka et al., 1999; Akhtar et al., 2001).

In arid and semi-arid regions, native lime content in the soil is usually high enough to create a calcareous condition. Calcareous soils contain free particles of calcium and/or magnesium carbonate (Hach Company, 1993). Addition of WVT to the soil will not reduce native soil lime content. Growth reductions in VT substrates might be partially due to slight increase in soil pH which might have led to mineral fixation and inhibition of plant nutrient uptake. The losses of N by volatilization as ammonia (NH_3) increase with increasing soil pH above 7 (Koelliker and Kissel 1988). As much as 70% of fertilized N applied to the soil surface could be lost by NH_3 volatilization (Whitehead and Raistrick 1990; Sigunga et al. 2002). The availability of P could also be inhibited by the presence of high calcium carbonate content. According to Hopikins and Ellsworth (2005) the reduction of phosphorus availability in calcium carbonate rich soils is driven by the reaction of phosphorus with calcium, with the lowest solubility of calcium phosphate ($CaPO_4$) at about pH 8.

Environmental stresses such as variable drought and low soil fertility are the main causes for low productivity in arid and semi-arid regions of Jordan. Using the suitable soil conditioner is one solution to minimize evaporation and conserve soil moisture. Many commercial companies market VT in Jordan under the name of zeolite with absence of the quality control on this product. Currently, the Jordanian standards and metrology organization will establishe and publish standrad specifications for the zeolitic tuff as a soil conditioner, which will provide a quality control of the national and global marketing of this product. Using wrong types of VT especially alkaline ones with high salt, Na and $CaCO_3$ contents will lead to more negative effects on plant growth than positive effect as a water adsorber. Inorganic soil amendment such as zeolitic tuff is recommended to reduce the water deficit effects and to enhance soil water holding capacity (Burriesci et al., 1984; Al-Busaidi et al., 2008). The use of zeolite as soil amendment led to an increased yield (Ming et al. 1995; Baikova and Semekhina, 1996; Loboda 1999), decrease in the demand of fertilizers (Chen and Gabelman, 1990; Loboda, 1999; Kavoosi 2007) and reduction in the leaching of nutrients (Pivert et al., 1997). Zeolite is applied to agricultural soils as a carrier of slow-release fertilizers, insecticides, fungicides and herbicides, as a trap for heavy metals in soils and to improve the quality of saline water and soils (Allen et al., 1993; Kithome et al., 1999; Mumpton, 1999; Gul et al., 2005; Ghrair et al., 2009). Zeolites were used in various crops including vegetables, fruit trees and field crops, as a soil conditioner in order to improve drainage and aeration, reduce leaching of pesticides and fertilizers from the soil and save moisture in the growing medium (Ming and Dixon, 1986; Ibrahim et al., 2001; Mohammad et al., 2004; Gul et al., 2005; Noor et al., 2006).

Results showed that all tuff treatments led to drastic reduction in plant biomass. The economic vegetative yied (i. e. Plant above ground biomss) was reduced in a pecentage ranged from 39% to 72%. At the same time, the water consumption was reduced in the same magnitude as the biomass (46.5 to 67.8%). This could be explaine by the fact that water consumption (transpiration) was simply declined because tuff amendment stressed the plant and resulted in a much lower biomass production (photosynthesis). Given that the amount of $CaCO_3$ in VT approximately equivalent to that estimated in pure soil, and that VT caused slight increases in salt content and pH in VT amended soil treatments. It could be concluded that salinity and carbonate contents have minimal effect on growth rate if the water content of the growing media is kept close to field capacity of pure soil. Therefore, yield reductions in VT amended soil may stand on the quantity of water applied and water potential of growing VT substrates. Irrigations were scheduled in this experiment to apply an optimum quantity by adding 80% of available water that used in the pure soil treatment. This could lead to a conclusion that the main factor that apparently affect the growth (both root and vegetative) of salvia plant is the water potential of pure VT and/or VT amended soils and the nature of VT substrate itself. Root growth in VT pure soil treatment and VT amended soils might be affected by water excess (as a result of high water potential) around roots through the depletion of oxygen, leading to reduced root respiration and other vital plant physiological processes, as well as the production and accumulation of phytotoxic materials such as sulfides and the lower monocarboxylic acids (Rigaux, L. R. and Singh, 1977; Armstrcng and Drew 2000).

In conclusion, the disadvantageous effects of VT on plant growth might be due to the high water potential of VT which might cause depletion of oxygen in VT amended soils leading to reduced root respiration and partially due to slight increase of salt content and pH in VT substrates. Further research on the comparative advantages of other types of Jordanian VT, particularly those with high zeolite and low salt and calcium carbonate content are highly recommended.

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تأثير الرماد البركاني الأردني الطبيعي على نمو وتوفير مياه الري ومحتوى الأوراق من العناصر لنبات الميرامية

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ملخـص

تعد ظروف الإجهاد، مثل: نقص ماء التربة وقلة خصوبتها التربة من الأسباب الرئيسة لنقص الإنتاجية في المناطق الجافة وشبة الجافة، حيث تعد محسنات التربة احد الحلول للتقليل من التبخر في التربة و تحسين كفائه استخدام الغذاء. تمت هذه الدراسة لفحص تأثير الرماد البركاني المعرض لعمليات التجوية وذلك غير المعرض التجوية (الطازج) والموجود في السوق الأردني على نمو وتوفير مياه الري ومحتوى الأوراق من العناصر في محصول الميرامية. أظهرت الدراسة ان هناك نقصا معنويا في جميع صفات النمو مع زيادة معدل إضافة الرماد البركاني، حيث كانت أعلى نسبة نقص في النمو عند زراعة النباتات في الرماد البركاني النقي. كانت هناك زيادة معنوية في تركيز الصوديوم (على مستوى معنوي 5%) من مرتين إلى ثلاث مرات، كما كان هناك نقص في بعض العناصر الضرورية مثل النيتروجين واالحديد والمنغنيز (على مستوى معنوي 5%) مع إضافة الرماد البركاني. كان هناك توفير في كمية استهلاك الماء في الترب المضاف اليها الرماد البركاني، حيث كانت نسبة التوفير في الماء تتراوح ما بين 46.5 – 67.8% وكان هناك في الوقت نفسه نقص في الكتلة الحيوية للنبات مع اضافة الرماد البركاني حيث كانت نسبة النقص تتراوح ما بين 39-72% و تبعا لذلك لم تكن هناك فروقات في كفاءة استخدام الماء ما بين النباتات النامية ب او دون رماد بركاني. إن القدرة العالية للرماد البركاني في الاحتفاظ بالماء (تستطيع احداث زيادة في الماء و المجموع الجذري) وتستطيع بالفعل التداخل مع امتصاص الماء مع الجذور المحرومة من الأكسجين و يؤدي الى نقص في النمو، وأن نقص النمو في الترب الممزوجة بالرماد البركاني قد يعود جزئيا الى الزيادة الطفيفة في ملوحة و درجة التركيز النيتروجني في وسط النمو. هناك حاجة لمزيد من الدراسات لفحص تأثير مصادر أخرى من الرماد البركاني، خصوصا ذلك الذي يحوي نسبة عالية من الزيولايت و نسب منخفضة من الملوحة و كربونات الكالسيوم.

الكلمات الدالة: التوفير في مياه الري، محتوى الاوراق من العناصر، الإجهاد الملحي، الرماد البركاني، الإجهاد المائي.

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